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(54) Method for field monitoring of a phased array microwave landing system far field antenna pattern employing a near field correction technique.

Methode zur Überwachung der Fernfeldcharakteristik einer phasengesteuerten Antenne für ein Mikrowellenlandesystem unter Verwendung einer Nahfeldkorrekturtechnik.

Procédé de contrôle de champ d'une configuration d'antenne de champ eloigné d'un système d'atterrissage par micro-ondes à réseau d'éléments à phase variable au moyen d'une technique de correction du champ proche.

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WO-A-90/12327 **US-A- 4 926 186**

- **IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION vol. 33, no. 12, December 1985, NEW YORK pages 1313 - 1327 RONEN ET AL. 'Monitoring Techniques for Phased-Array Antennas'**
- **ANTENNAS AND PROPAGATION SOCIETY SYMPOSIUM 1991 DIGEST vol. 3, June 1991, NEW YORK pages 1462 - 1465 , XP000239290 LI ET AL. 'Evaluation of Far-Field Pattern from Near-Field Measurement Using a Near-Field Imaging Technique.'**
- **IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION vol. 34, no. 1, January 1985, NEW YORK pages 30 - 45 YAGHJIAN 'An Overview of Near-Field Antenna Measurements.'**

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Description

The present invention provides an improved method for error-corrected near field monitoring of the far field pattern generated by a Microwave Landing System (MLS) transmitting antenna. More particularly, the invention relates to a method of MLS near field signal monitoring which reconstructs the entire main beam portion of the far field pattern generated by a scanning phased array antenna, and does so in a fashion which compensates for near field effects.

Field monitors are employed in airport Microwave Landing Systems to check the accuracy and quality of the signal radiated by the MLS antenna. For realism, the field monitor should measure the same guidance beam as would be measured by an airborne MLS receiver. However, such realism requires that the monitor antenna be located in the far field of the MLS antenna, far removed from the distortions encountered in the near field of the MLS antenna. It is generally recognized that far field antenna pattern measurements should be conducted at a minimum distance of $2D^2/\lambda$, where D is the aperture of the antenna and λ is the wavelength of the radiated signal, if near field distortions are to be avoided.

If this criterion is followed for a typical MLS antenna where D is 3.657 m, λ = 6.1 cm (D = 12 feet, λ = 0.2 feet), the monitor antenna must be located at a minimum distance of 439 m (1440 feet) from the MLS antenna.

Few airport environments provide an obstacle-free path of adequate length to permit antenna pattern measurements to be conducted in the far field. Moreover, the signals received by the monitor would likely be corrupted by refractions and reflections from airport installations and from aircraft movements on the runway. The preferred distance for location of the monitor antenna is therefore about 46 m (150 feet) from the MLS antenna, ahead of such obstructions as runway approach lights. Clearly, the monitor antenna is then well into the near field of the MLS antenna and cannot measure the guidance beam as would a distant airborne receiver.

Near field distortion effects occur because the r.f. path delays between the monitor antenna and radiating elements of the array at the outer edges of the transmitting antenna aperture are significantly different from the path delays between the monitor antenna and radiating elements near the center of the transmitting antenna aperture. Near field effects may be overcome by applying certain compensating factors to the transmitting antenna to cause the guidance beam to be refocused at the monitor antenna. Such a procedure is obviously unacceptable as it results in distortion of the far field guidance beam.

An integral monitor antenna is known and has been used to monitor performance of the MLS transmitting antenna. The integral monitor antenna comprises a slotted waveguide or a similar array of antenna elements that extends completely across the transmitting antenna aperture in very close proximity thereto. Compensation for near field effects is built into the integral monitor antenna so that the signal output of the integral monitor antenna simulates the signal output of a monitor antenna located in the far field of the transmitting antenna. However, it is impractical to duplicate the structure of the integral monitor antenna, considering the necessary changes in scale, when the monitor antenna is to be located at a distance of about 46 m (150 feet) from the transmitting antenna.

WO 90/12327 describes a microwave landing system which provides a monitoring system for monitoring, in the near field, the signal from a transmitting antenna comprising: monitor means; and modifying means located in the near field for receiving the signal from the transmitting antenna and inputting to the monitor means a signal approximating that which would be received in the far field, the modifying means comprising: a plurality of spaced apart individual antenna elements disposed along a line parallel to the major axis of the transmitting antenna; and power divider means connected to the antenna elements to phase shift the signal received by some of the antenna elements, such that the output of said power divider means approximates said signal which would be received in the far field.

Monitoring techniques for phased array antennas are disclosed by J. Ronen and R. Clarke in IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION, Vol. 33, No. 12, pages 1313-1327, Dec. 1985. Particularly, the "near field focussing" method is suggested using the properties of the Fresnel integral for the near field to far field transformation.

Li and Huang in ANTENNAS AND PROPAGATION SOCIETY SYMPOSIUM, 1991 DIGEST, Volume 3, pages 1462-1465 propose a method to evaluate the far-field scattering pattern from the measured near-field data. The authors indicate that the basic concept of this method is that the far-field data (or the Fourier space data) and the complex far-field image have a FT relationship, and the complex far-field image and the near-field image reconstructed by the spherical back-projection method have similar appearance. In other words, the far-field image can be approximated by the near-field image and the far-field scattering pattern can then be evaluated by inversely Fourier transforming the complex near-field image. The primary advantage of this method is that the far-field scattering patterns for different frequencies can be achieved simultaneously. However, this method is an approximate method. The far-field data so derived are valid only for those points contained in the original frequency and angular windows; and the scattering mechanisms of the object and the interpolation procedure can affect accuracy of the derived results.

The present invention utilizes the Fourier relationship between the near-field pattern and the aperture function to reconstruct the far-field pattern of the MLS antenna from sample measurements taken by a monitor antenna located in the near-field of the MLS antenna.

US-A-4926186 discloses a method in which signal samples, taken by an integral monitor antenna or a monitor antenna located in the far field at non-uniform intervals, are processed by Fourier transforms to provide the aperture function of the MLS antenna. Obtaining the aperture function in such manner permits the identification of individual phase shifters or other components of the MLS antenna that may be faulty.

US-A-4 553 145, discloses a method based on Fourier transforms for obtaining the far field pattern of a rotating antenna from measurements taken in the near field. The method collects near field signal samples at critical points of the antenna pattern for a partial reconstruction of the far field pattern. Close synchronization of angle transducers at the transmitting antenna pedestal and at the monitor receiver is required.

The present invention provides a method for monitoring of the far field antenna pattern of a phased array using a monitor antenna located in the near field of said phased array antenna whereby the far field pattern of said phased array antenna is obtained.

According to the invention, said phased array antenna transmits a beam that is scanned at a constant rate, the scan angle of said beam relative to the boresight of said phased array antenna, at any time (t), being $\beta_s(t)$;

computing the Fourier transform of complex conjugates of the phase error term contained in the pattern of said phased array antenna, said phase error term being due to said location of said monitor antenna in the near field;
measuring the antenna pattern of said phased array antenna received by said monitor antenna to provide the measured near field patternof said phased array antenna;
said step of measuring including the steps of:
applying the signals induced in said monitor antenna by said beam of said phased array antenna to a receiver to provide a signal output corresponding to the near field pattern of said phased array antenna;
detecting in a quadrature detector said output of said receiver to provide complex real and imaginary components of said output;
collecting samples from both said real and imaginary components of said receiver output at times t_i, such that said times t_i correspond to equal increments of sin $\beta_s(t)$, said collected samples constituting said measured near field pattern of said phased array antenna; and
convolving said measured near field pattern with said computed Fourier transform to obtain the far field pattern of said phased array antenna.

Accordingly, it is an object of the present invention to provide a method for near field beam monitoring of a scanning phased array MLS antenna which provides a complete reconstruction of the far field beam pattern, and which can be accomplished during normal operation of the array.

The near field antenna pattern can be represented as the product of the aperture function f(x) and a quadratic phase error term q(x). Using the Fourier convolution theorem in the spatial frequency domain, the near field pattern F $[p,R_0]$ is:

$$F[p,R_0] = F(p) \otimes Q(p)$$

where F(p) is the far field pattern and also the transform of f(x) and Q(p) is the transform of q(x). A correction term Q'(p), which is the complex conjugate of Q(p), is convolved with $F[p,R_0]$ such that:

$$F[p,R_0] \otimes Q'(p) = F(p) \otimes Q(p) \otimes Q'(p) = F(p),$$

since, $Q(p) \otimes Q'(p) = \delta(p)$, the delta function.

Brief Description of the Drawings

Fig. 1 is an illustration of a typical MLS field monitor arrangement.

Fig. 2 is a diagram from which the phase error term of the near field antenna pattern can be calculated.

Fig. 3 is a block diagram of a near field monitor receiver according to the invention.

Fig. 4 is a block diagram of shift register means for convolving complex correction coefficients with the near field antenna pattern measurements.

Fig. 5 is a flow chart showing the processing of near field antenna pattern measurements to produce a far field antenna pattern.

Fig. 6 shows a near field pattern of a typical MLS antenna as measured by a monitor located 100 feet from the MLS antenna.

Fig. 7 shows the pattern of Fig. 6 after refocusing according to the invention.

Fig. 8 shows the far field pattern of the MLS antenna used in preparation of Fig. 6, as measured by a monitor located in the far field; and,

Fig. 9 is a graph showing the error between the corrected near field pattern of Fig. 7 and the far field pattern of Fig. 8.

Detailed Description of the Invention

Fig. 1 illustrates a typical MLS and near field monitor installation at an airport. A phased array MLS antenna 10 is located beyond the stop end 11 of a runway 12 and obstructions thereabout, such as runway lights 14. Antenna 10 transmits an azimuth guidance beam 13 toward the approach end of runway 12. Beam 13 is scanned through an angle β_s about the runway center line 15. Antenna 10 is typically located so that the boresight of the antenna coincides with the runway center line, as shown, but locations offset from the runway center line are allowed. Antenna 10 is typically located about 61 m (200 feet) from the nearest obstruction, such as lights 14. A field monitor antenna 16 is located in the near field of antenna 10 within the scan coverage area of beam 13, suitably at a distance of about 46 m (150 feet).

Fig. 1 shows a typical MLS installation for azimuth guidance. It will be understood that a complete MLS further includes a separate phased array antenna for generating a guidance beam that is scanned in elevation, and that the invention is equally applicable to the near field monitoring of the antenna pattern of the elevation antenna.

Referring to Fig. 2, phased array antenna 10 comprises a plurality N of radiating elements 18 spaced equally at distances Δx across the aperture of the antenna. The normal to the linear array of elements 18, line A-A, is the boresight of the antenna. Monitor antenna 16 is positioned at a distance R_0 from the center O of the array at a bearing angle B to the boresight A-A. The distance from monitor antenna 16 to any element of the array is $R_0 \pm \Delta R$. Selecting element 18' as an example, the solution of triangle OCD is:

$$(R_0+\Delta R)^2=R_0^2+x_k^2+2R_0x_k^2\sin\beta \qquad (1)$$

For $x_k/R_0 << 1$,

$$\Delta R \approx R_0\left[\frac{x_k}{R_0}\sin\beta+\frac{1}{2}\left(\frac{x_k}{R_0}\right)^2\right] \qquad (2)$$

The quadratic term of equation (2) appears as the phase error term in the near field antenna pattern $F(\beta,R_0,t)$, equation (3), for a phased array antenna 10 having N elements 18, measured by a monitor antenna 16 located at a distance R_0 from the center of the array.

$$F(\beta,R_0,t)=\sum_{k=0}^{N-1}a_k e^{j\frac{2\pi}{\lambda}x_k\sin\beta}e^{-j\frac{2\pi}{\lambda}x_k\sin\beta_s(t)}e^{-j\frac{\pi}{\lambda R_0}x_k^2} \qquad (3)$$

where:

a_k is the voltage excitation of element (k), k = 0,1...N-1;
β is the bearing angle of monitor antenna 16 from A-A; and

$$x_k=\Delta x\left(k-\frac{N+1}{2}\right)$$

Equation (3) contains three exponential terms. The first (which is a function of β) being the spatial term, the second (a function of $\beta_s(t)$) the temporal term, and the third (a function of R_0) the quadratic defocusing term. The far field pattern of antenna 10 can be obtained from equation (3) by allowing R_0 to approach infinity, thus:

$$F(\beta,\infty,t)=\sum_{k=0}^{n-1}a_k e^{j\frac{2\pi}{\lambda}x_k\sin\beta}e^{-j\frac{2\pi}{\lambda}x_k\sin\beta_s(t)} \qquad (4)$$

Equation (3) is a Fourier transform of the aperture function with the temporal exponential term forming the Fourier kernal. When a phase correction term,

$$e^{j\frac{\pi}{\lambda R_0}x_k^2} \qquad (4a)$$

corresponding to the conjugate of the quadratic phase error term, is imposed on the aperture function,the following characterization of the far field pattern, G(β,∞,t), results:

$$G(\beta,\infty,t)=\sum_{k=0}^{N-1}\left[a_k e^{j\frac{2\pi}{\lambda}x_k\sin\beta}e^{-j\frac{\pi}{\lambda R_0}x_k^2}\right]\left[e^{j\frac{\pi}{\lambda R_0}x_k^2}\right]e^{-j\frac{2\pi}{\lambda}x_k\sin\beta_s(t)} \qquad (5)$$

which is:

$$G(\beta,\infty,t)=\sum_{k=0}^{n-1}f(\beta,R_0,x_k)\,r(R_0,x_k)\,e^{-j\frac{2\pi}{\lambda}x_k\sin\beta_s(t)} \qquad (6)$$

where $f(\beta,R_0,x_k)$ is the effective aperture function of the transmitting array measured at the field monitor location (including both the spatial and the defocusing terms) and $r(R_0,x_k)$ is the desired refocusing term. Although $r(R_0,x_k)$ can be computed from equation (4a), $f(\beta,R_0,x_k)$ is not directly measurable in this instance.

In applying the method while the MLS antenna is operating with a normal scan, the near field antenna pattern is sampled at non-uniform intervals of time, t_i, corresponding to equal increments of sin $\beta_s(t)$. More particularly, the samples are taken at times t_i such that:

$$t_i = \frac{\sin^{-1}\left[\frac{\lambda}{2\Delta x}\left(1-\frac{2i}{M}\right)\right]}{\otimes_o} - t_0\ x)$$

where:

θ_s is the scan rate of the MLS antenna beam;
t_0 is the time at which the beam scans through 0 degrees; and
i = 0, 1,....N-1; so that:

$$\sin\beta_s(t_i)=\frac{\lambda i}{\Delta x M} \qquad (8)$$

By substituting equation (8) into equation (6), the following Discrete Fourier Transform is obtained:

$$G(\beta,\infty,i) = \sum_{k=0}^{N-1} f(\beta,R_0,k)\, r(R_0,k)\, e^{-j\frac{2\pi}{N}\left(k-\frac{N+1}{2}\right)} \qquad (9)$$

Rearranging equation (9),

$$G(\beta,\infty,i) = e^{j\frac{2\pi(N+1)i}{2N}} \sum_{k=0}^{N-1} f(\beta,R_0,k)\, r(R_0,k)\, e^{-j\frac{2\pi ki}{N}} \qquad (10)$$

Finally,

$$G(\beta,\infty,i) = e^{j\frac{2\pi(N+1)i}{2N}} F(\beta,R_0,i) \otimes R(R_0,i) \qquad (11)$$

The final step illustrated above relies upon the Fourier property that the transform of the product $f(\beta,R_0,k)\ r(R_0,k)$ is the convolution of the individual transforms $F(\beta,R_0,i) \otimes R(R_0,i)$. The transform $F(\beta,R_0,i)$ is obtained by sampling the near field antenna pattern at intervals t_i. The coefficients $R(R_0,i)$ are precomputed from equation (12) below using the specific values of R_0, X_k, and N that are dependent on a particular monitor installation site and MLS antenna. The value of M is selected to provide a sufficient number of samples to obtain the accuracy desired. Suitably, M = 256 and typically N = 48.

$$R(R_0,m) = e^{j\frac{2\pi(N+1)m}{2N}} \sum_{k=0}^{N-1} r(R_0,k)\, e^{-j\frac{2\pi mk}{N}}$$

$$R(R_0,m) = e^{j\frac{2\pi(N+1)m}{2N}} \sum_{k=0}^{N-1} e^{j\frac{\pi}{\lambda R_0}x_k^2}\, e^{-j\frac{2\pi mk}{N}} \qquad (12)$$

Referring to Fig. 3, the MLS beam signals $F(\beta,R_0,t)$ induced in monitor antenna 16 are amplified and converted to i.f. frequency by a receiver 21. A quadrature detector 22 converts the i.f. output of receiver 21 into complex real and imaginary components of $F(\beta,R_0,t)$. The analog outputs of detector 22 are applied to an A/D converter 23 that is controlled by a timer 20 so as to produce digitized real and imaginary samples of $F(\beta,R_0,t)$ at intervals t_i, where t_i is defined in equation (7). The real and imaginary samples $F(\beta,R_0,m)$ from converter 23 are stored in sample storage 24 for use in a complex convolution routine or for application to a complex convolver 25 that convolves the samples with the precomputed coefficients $R(R_0,i)$. The complex outputs of convolver 25, comprising the real and imaginary components of $G(\beta,\infty,t_m)$, are stored in memory 26 whence they may be retrieved for conversion into points of signal amplitude, A, at times, t, for display, plotting, or other processing of the far field antenna pattern of the MLS antenna. Conversion of the components stored in memory 26 into amplitudes merely involves the simple calculation
$A = [(\text{real})^2 + (\text{imag.})^2]^{1/2}$.

Fig. 4 is a simplified block diagram of a shift register means for performing the operations of convolver 25. It will be understood that such shift register means are provided for processing the complex sample outputs of A/D converter 23 via complex multiplication and summation operations. Samples from storage 24 are successively applied to an M stage shift register 30 comprising stages 31-m-33 spaced at intervals corresponding to equal increments of $\sin\beta_s(t)$. The output 35-m'-38 of each stage 31-m-33 is weighted with the appropriate one of the precomputed coefficients $R(R_0,m)$, i.e., the mth stage output is weighted with the mth coefficient, so that as each of the i samples is clocked through

a register stage m, the product of that sample and the mth coefficient is output to an accumulator 40. When the first (i = 1) sample is clocked out of the final register stage 33, the Mth stage, the contents of accumulator 40 are shifted into memory 26. The new contents of accumulator 40 are shifted into storage 26 as the second, and each succeeding sample, is clocked out of register stage 33. Processing of the near field samples for conversion into the far field pattern is completed when all M samples of the measured waveform $f(\beta,R_0,t)$ have been passed through convolver 25.

Fig. 5 is a flow chart describing the processing of samples of the near field antenna pattern to obtain the far field pattern. Processing begins (box 40) with the collection of M real and imaginary samples of the near field pattern at times t_i. These samples are placed in storage 24 (Fig. 3). The real and imaginary samples are processed separately in a routine, or in a convolver as shown in Fig. 4, the operation of which is shown by boxes 41-44. A sample is called from storage (41) and an N-point convolution (42) is performed thereon in which each set of N consecutive samples is multiplied in turn by the corresponding correction coefficients $R(R_0,1)...R(R_0,M)$, with the result of each multiplication being accumulated (43), and the accumulated sum is placed in storage (44) as the multiplication of each sample m by the coefficient $R(R_0,M)$ is completed. Decision block 45 iterates the steps of sample fetching, convolving, sum accumulation, and storage until all M samples have been processed.

Fig. 6 shows the near field pattern of an MLS phased array antenna as measured by a monitor located 30.5 m (100 feet) from the MLS antenna but without refocusing according to the invention. The MLS operated at 5060.7 Mhz.

Fig. 7 shows the pattern of the MLS antenna measured from the near field as in Fig. 6 with refocusing according to the invention. Fig. 8 shows the pattern of the MLS antenna used in preparation of Fig. 6 as measured by a monitor located in the far field; and

Fig. 9 shows the difference between the patterns of Fig. 7 and Fig. 8.

A development of the mathematical basis of the invention that is more complete than that given above follows.

The discrete convolution of equation (11) is:

$$U(m) = \frac{1}{M} \sum_{\ell=-\frac{M}{2}}^{\frac{M}{2}-1} F(\ell)\, R\,(m-\ell) \qquad (12)$$

Using the Fourier kernal defined in equation (11), the individual transform terms are as follows:

$$F(\beta, R_0, m) = e^{j\frac{2\pi(N+1)m}{2M}} \sum_{k=0}^{N-1} f(\beta, R_0, k)\, e^{-j\frac{2\pi mk}{M}}$$

$$R(R_0, m) = e^{j\frac{2\pi(N+1)m}{2M}} \sum_{k=0}^{N-1} r(R_0, k)\, e^{-j\frac{2\pi mk}{M}}$$

$$U(m) = \frac{1}{M} \sum_{\ell=-\frac{M}{2}}^{\frac{M}{2}-1} F(\beta, R_0, \ell)\, R(R_0, m-\ell)$$

$$U(m) = \frac{1}{M} \sum_{\ell=-\frac{M}{2}}^{\frac{m}{2}-1} \left[e^{j\frac{2\pi(N+1)\ell}{2M}} \sum_{k=0}^{N-1} f(\beta, R_0, k)\, e^{-j\frac{2\pi\ell k}{M}} \right] \times$$

$$\left[e^{j\frac{2\pi(N-1)(m-\ell)}{2M}} \sum_{n=0}^{N-1} r(R_0, n)\, e^{-j\frac{2\pi(m-\ell)k}{M}} \right]$$

$$U(m) = \frac{1}{M} \sum_{\ell=-\frac{M}{2}}^{\frac{M}{2}-1} e^{j\frac{2\pi(N+1)m}{2M}} \sum_{k=0}^{N-1} \sum_{n=0}^{N-1} f(\beta, R_0, k) \times$$

$$\left[e^{-j\frac{2\pi(k-n)\ell}{M}}\, e^{-j\frac{2\pi mn}{M}} \right] \qquad (13)$$

It is well known that for Discrete Fourier Transforms:

$$\delta_{(k-n)} = \frac{1}{M} \sum_{\ell=-\frac{M}{2}}^{\frac{M}{2}-1} e^{-j\frac{2\pi\ell(k-n)}{M}} \qquad (14)$$

$$= \begin{cases} 1 & \text{if } k-n \\ 0 & \text{otherwise} \end{cases}$$

Applying equation (14) to equation (13) eliminates all terms where k is not equal to n, and yields:

$$U(m) = e^{j\frac{2\pi(N+1)m}{2M}} \sum_{n=0}^{N-1} f(\beta, R_0, n)\, r(R_0, n)\, e^{-j\frac{2\pi mn}{M}}$$

$$U(m) = \sum_{n=0}^{N-1} f(\beta, R_0, n)\ r(R_0, n)\ e^{-j\frac{2\pi m\left(n-\frac{N-1}{2}\right)}{N}} \qquad (15)$$

Finally, substituting the fully expanded forms of $f(*)$ and $r(*)$ into equation (15):

$$U(m) = \sum_{n=0}^{N-1}\left[a_n e^{j\frac{2\pi}{\lambda} x_n \sin\beta} e^{-j\frac{\pi}{\lambda R_0} x_n^2}\right]\left[e^{j\frac{\pi}{\lambda R_0} x_n^2}\right] e^{-j\frac{2\pi}{\lambda} x_n \sin\beta_s(t_D)}$$

$$U(m) = \sum_{n=0}^{N-1} a_n e^{j\frac{2\pi}{\lambda} x_n \sin\beta} e^{-j\frac{2\pi}{\lambda} x_n \sin\beta_s(t_D)}$$

$$\cdot F(\beta, \infty, t_m)$$

which is the far field pattern given by equation (4).

Claims

1. A method for monitoring of the far field antenna pattern of a phased array antenna using a monitor antenna located in the near field of said phased array antenna whereby the far field pattern of said phased array antenna is obtained, characterized by said phased array antenna transmitting a beam that is scanned at a constant rate, the scan angle of said beam relative to the boresight of said phased array antenna, at any time (t), being $\beta_s(t)$;

   measuring the antenna pattern of said phased array antenna received by said monitor antenna to provide the measured near field pattern of said phased array antenna;

   said step of measuring including the steps of:

   applying the signals induced in said monitor antenna by said beam of said phased array antenna to a receiver to provide a signal output corresponding to the near field pattern of said phased array antenna; and
   detecting in a quadrature detector said output of said receiver to provide complex real and imaginary components of said output;

   characterized in that said step of measuring further includes the steps of computing the Fourier transform of complex conjugates of the phase error term contained in the pattern of said phased array antenna, said phase error term being due to said location of said monitor antenna in the near field at a bearing angle to the boresight,

   collecting samples from both said real and imaginary components of said receiver output at times t_i, such that said times t_i correspond to equal increments of sin $\beta_s(t)$, said collected samples constituting said measured near field pattern of said phased array antenna; and
   convolving said measured near field pattern with said computed Fourier transform to obtain the far field pattern of said phased array antenna.

2. A method according to Claim 1 characterized in that said computed Fourier transform comprises a sequence of correction coefficients $R(R_{10},m)$, where m = 1, 2,...M, and wherein said step of convolving said measured near field pattern with said computed Fourier transform includes:

providing a shift register having a total of M successive stages m, where m = 1, 2,....M;
weighting the output at each stage m of said shift register with the corresponding one of said correction coefficients $R(R_0,m)$;
applying said collected samples of said real and imaginary components sequentially to said shift register;
shifting said applied samples serially through said shift register;
accumulating the sum of the weighted outputs of said shift register as said samples are shifted through said shift register; and
storing said accumulated sum at the time the first of said applied samples is shifted out of the Mth stage of said shift register, and at the time each succeeding one of said applied samples is shifted out of the Mth stage of said shift register, said stored accumulated sums constituting the complex components of the far field pattern of said phased array antenna.

Patentansprüche

1. Verfahren zur Überwachung der Fernfeld-Strahlungscharakteristik einer phasengesteuerten Gruppenantenne unter Verwendung einer im Nahfeld der besagten phasengesteuerten Gruppenantenne befindlichen Überwachungsantenne, wodurch die Fernfeldcharakteristik der besagten phasengesteuerten Gruppenantenne erhalten wird, dadurch gekennzeichnet, daß die besagte phasengesteuerte Gruppenantenne einen Strahl aussendet, der mit einer konstanten Rate abgetastet wird, wobei der Abtastwinkel des besagten Strahls zur Keulenachse der besagten phasengesteuerten Gruppenantenne zu jeder Zeit (t) $\beta_s(t)$ beträgt;

   Messen der von der besagten Überwachungsantenne empfangenen Strahlungscharakteristik der besagten phasengesteuerten Gruppenantenne zur Bereitstellung der gemessenen Nahfeldcharakteristik der besagten phasengesteuerten Gruppenantenne;

   wobei der besagte Schritt des Messens folgende Schritte enthält:

   Anlegen der durch den besagten Strahl der besagten phasengesteuerten Gruppenantenne in der besagten Überwachungsantenne induzierten Signale an einen Empfänger zur Bereitstellung einer der Nahfeldcharakteristik der besagten phasengesteuerten Gruppenantenne entsprechenden Signalausgabe; und
   Erkennen der besagten Ausgabe des besagten Empfängers in einem Quadraturdetektor zur Bereitstellung von komplexen Real- und Imaginärteilen der besagten Ausgabe;

   dadurch gekennzeichnet, daß der besagte Schritt des Messens weiterhin folgende Schritte enthält:

   Berechnen der Fouriertransformierten komplexer Konjugierter des in der Charakteristik der besagten phasengesteuerten Gruppenantenne enthaltenen Phasenfehlergliedes, das darauf beruht, daß sich die besagte Überwachungsantenne im Nahfeld mit einem Seitenwinkel zur Keulenachse befindet,
   Probennahme aus sowohl Real- als auch Imaginärteilen der besagten Empfängerausgabe zu den Zeiten t_i, so daß die besagten Zeiten t_i gleichen Schritten von sin $\beta_s(t)$ entsprechen, wobei die besagten gesammelten Proben die besagte gemessene Nahfeldcharakteristik der besagten phasengesteuerten Gruppenantenne bilden; und
   Verknüpfung der besagten gemessenen Nahfeldcharakteristik mit der besagten berechneten Fouriertransformierten zum Erhalten der Fernfeldcharakteristik der besagten phasengesteuerten Gruppenantenne.

2. Verfahren nach Anspruch 1, dadurch gekennzeichnet, daß die besagte berechnete Fouriertransformierte eine Folge von Korrekturkoeffizienten $R(R_{10},m)$ umfaßt, wobei m = 1, 2, ...M, und wobei der besagte Schritt des Verknüpfens der besagten gemessenen Nahfeldcharakteristik mit der besagten berechneten Fouriertransformierten folgendes enthält:

   Bereitstellen eines Schieberegisters mit insgesamt M aufeinanderfolgenden Stufen m, wobei m = 1, 2, ...M;
   Gewichten der Ausgabe an jeder Stufe m des besagten Schieberegisters mit dem entsprechenden der besagten Korrekturkoeffizienten $R(R_0,m)$;
   Anlegen der besagten gesammelten Proben der besagten Real- und Imaginärteile sequentiell an das besagte Schieberegister;
   Durchschieben der besagten angelegten Proben seriell durch das besagte Schieberegister;
   Ansammeln der Summe der gewichteten Ausgaben des besagten Schieberegisters mit dem Durchschieben der besagten Proben durch das besagte Schieberegister; und
   Speichern der besagten angesammelten Summe zur Zeit, wenn die erste der besagten angelegten Proben

aus der Mten Stufe des besagten Schieberegisters hinausgeschoben wird und zu der Zeit, wenn jede nachfolgende der besagten angelegten Proben aus der Mten Stufe des besagten Schieberegisters herausgeschoben wird, wobei die besagten gespeicherten angesammelten Summen die komplexen Teile der Fernfeldcharakteristik der besagten phasengesteuerten Gruppenantenne bilden.

Revendications

1. Procédé de contrôle du diagramme de rayonnement d'antenne en champ distant d'une antenne réseau d'éléments à phase variable en utilisant une antenne de contrôle située dans le champ proche de ladite antenne réseau d'éléments à phase variable par lequel le diagramme de rayonnement en champ distant de ladite antenne réseau d'éléments à phase variable est obtenu, caractérisé par l'émission par ladite antenne réseau d'éléments à phase variable d'un faisceau qui est balayé à une fréquence constante, l'angle de balayage dudit faisceau par rapport à l'axe de ladite antenne réseau d'éléments à phase variable, à n'importe quel temps (t), étant $\beta_s(t)$;

la mesure du diagramme de rayonnement d'antenne de ladite antenne réseau d'éléments à phase variable reçu par ladite antenne de contrôle pour fournir le diagramme de rayonnement en champ proche mesuré de ladite antenne réseau d'éléments à phase variable ;

ladite étape de mesure comportant les étapes :

d'application des signaux induits dans ladite antenne de contrôle par ledit faisceau de ladite antenne réseau d'éléments à phase variable à un récepteur pour fournir un signal de sortie correspondant au diagramme de rayonnement en champ proche de ladite antenne réseau d'éléments à phase variable ; et
de détection dans un détecteur quadratique de ladite sortie dudit récepteur pour fournir les composantes réelle et imaginaire complexes de ladite sortie ;

caractérisé en ce que ladite étape de mesure comporte en outre les étapes de calcul de la transformée de Fourier de conjuguées complexes du terme d'erreur de phase contenu dans le diagramme de rayonnement de ladite antenne réseau d'éléments à phase variable, ledit terme d'erreur de phase étant dû audit emplacement de ladite antenne de contrôle dans le champ proche à un angle de gisement par rapport à l'axe d'antenne,

la collecte d'échantillons des deux dites composantes réelle et imaginaire de ladite sortie de récepteur à des temps t_i, de telle sorte que lesdits temps t_i correspondent à des incréments égaux de sin $\beta_s(t)$, lesdits échantillons collectés constituant ledit diagramme de rayonnement en champ proche mesuré de ladite antenne réseau d'éléments à phase variable ; et
la convolution dudit diagramme de rayonnement en champ proche mesuré avec ladite transformée de Fourier calculée pour obtenir le diagramme de rayonnement en champ distant de ladite antenne réseau d'éléments à phase variable.

2. Procédé selon la revendication 1, caractérisé en ce que ladite transformée de Fourier calculée comprend une séquence de coefficients de correction $R(R_{10}, m)$, où m = 1, 2, ... M, et dans lequel ladite étape de convolution dudit diagramme de rayonnement en champ proche mesuré avec ladite transformée de Fourier calculée comporte :

la fourniture d'un registre à décalage ayant un total de M étages successifs, où m = 1, 2, ... M ;
la pondération de la sortie au niveau de chaque étage m dudit registre à décalage avec le coefficient correspondant desdits coefficients de correction $R(R_0,m)$;
l'application desdits échantillons collectés desdites composantes réelle et imaginaire séquentiellement audit registre à décalage ;
le décalage desdits échantillons appliqués sériellement à travers ledit registre à décalage ;
l'accumulation de la somme des sorties pondérées dudit registre à décalage au fur et à mesure que lesdits échantillons sont décalés à travers ledit registre à décalage ; et
la mémorisation de ladite somme accumulée au moment où le premier desdits échantillons appliqués est sorti par décalage du M^e étage dudit registre à décalage, et au moment où chaque échantillon successif desdits échantillons appliqués est sorti par décalage du M^e étage dudit registre à décalage, lesdites sommes accumulées mémorisées constituant les composantes complexes du diagramme de rayonnement en champ distant de ladite antenne réseau d'éléments à phase variable.

BEST AVAILABLE COPY

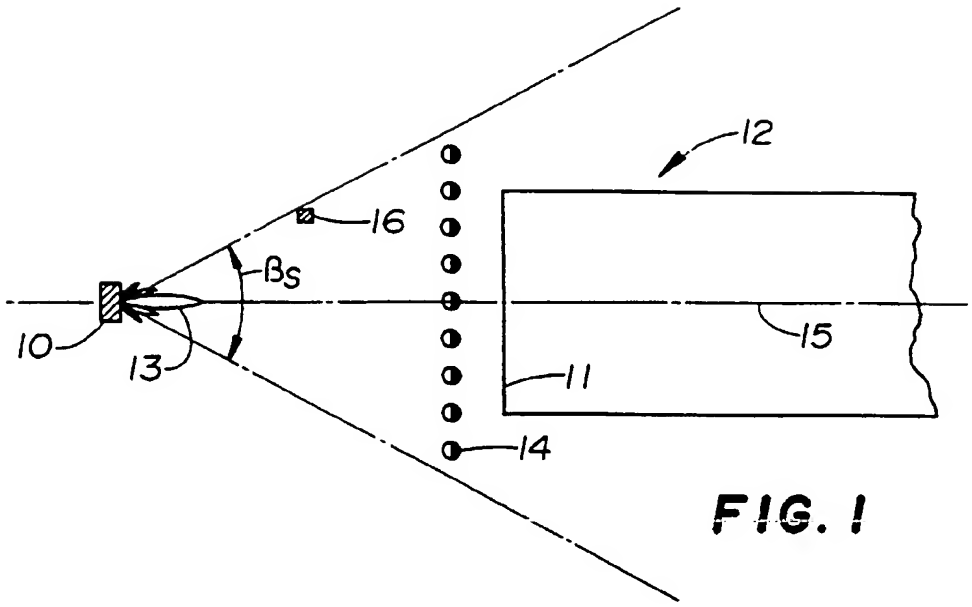

FIG. 1

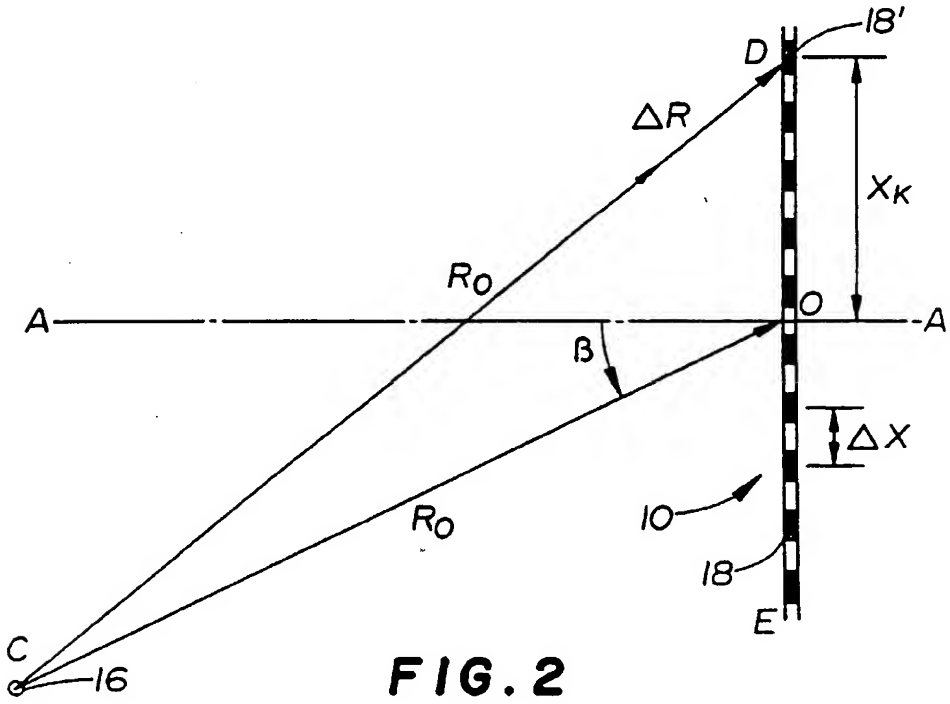

FIG. 2

BEST AVAILABLE COPY

BEST AVAILABLE COPY

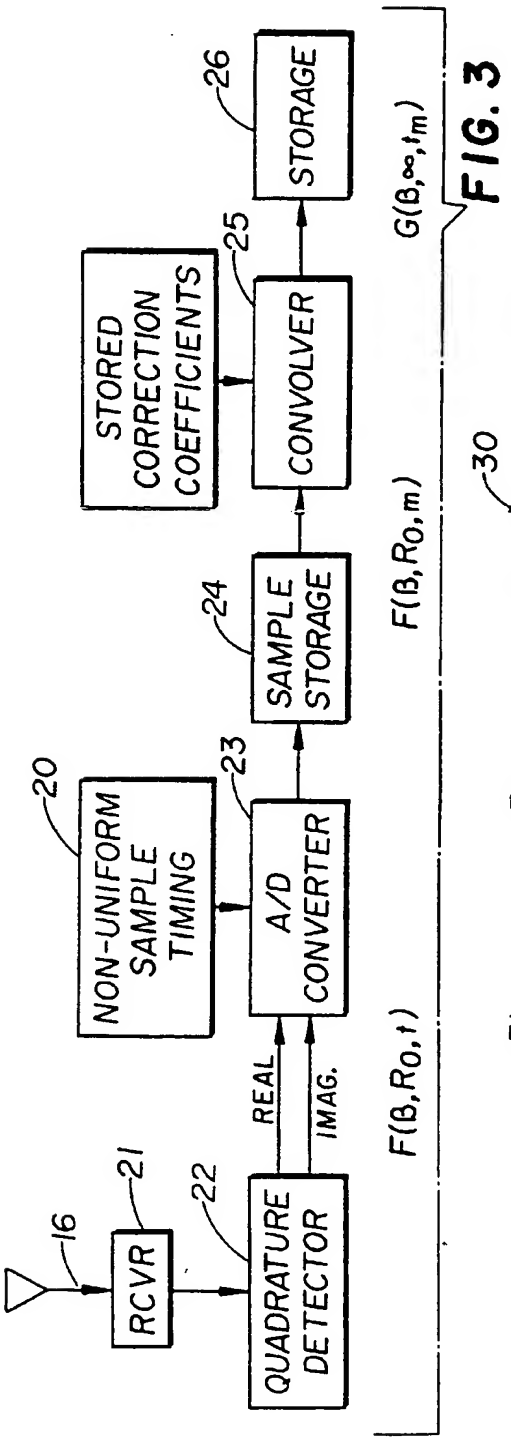

FIG. 3

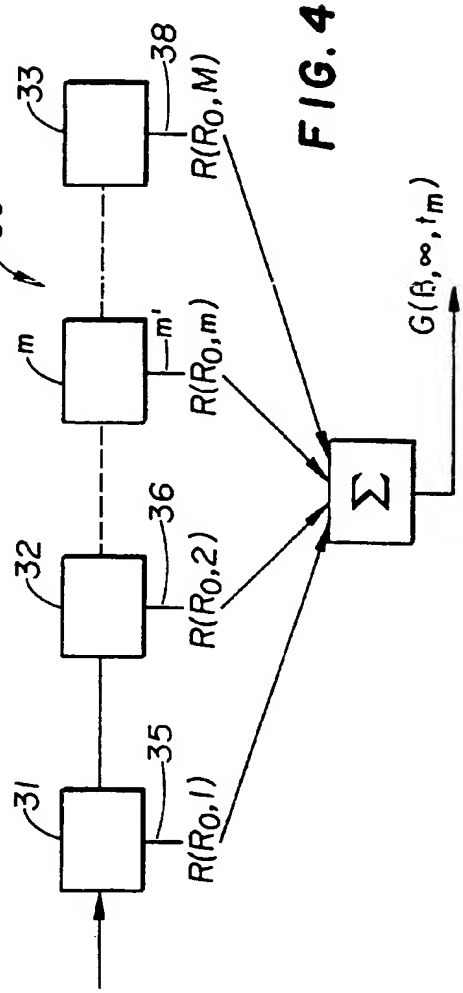

FIG. 4

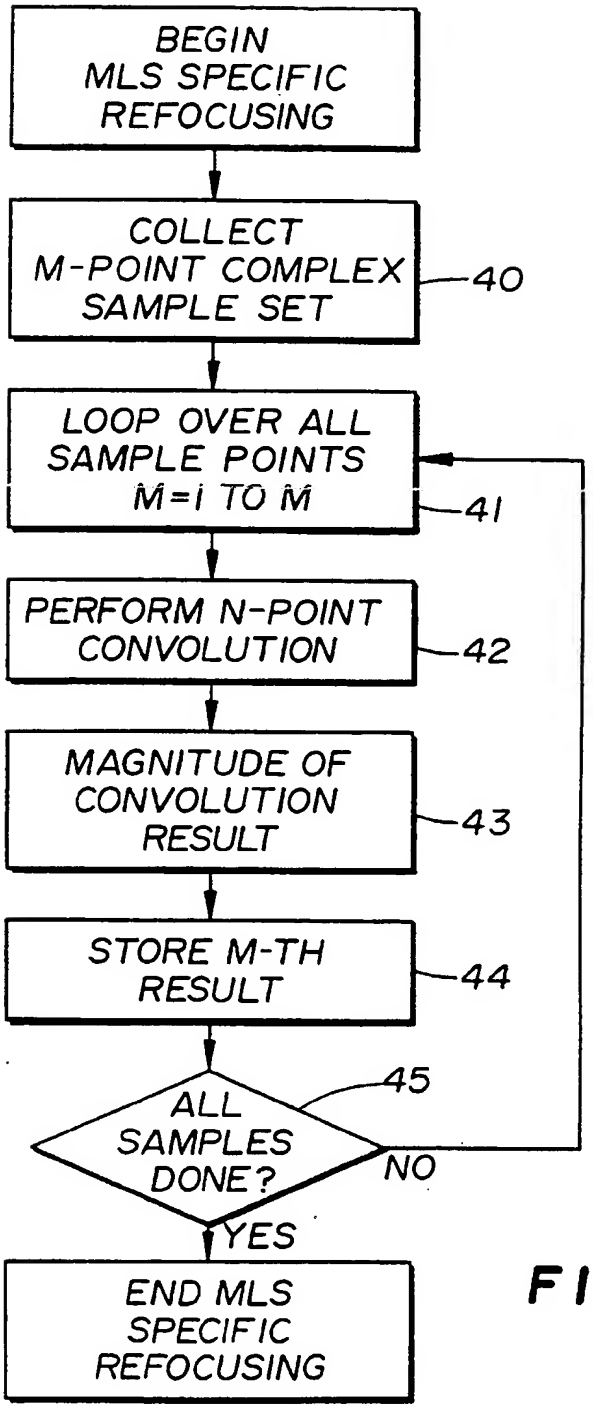
BEGIN MLS SPECIFIC REFOCUSING
COLLECT M-POINT COMPLEX SAMPLE SET
40
LOOP OVER ALL SAMPLE POINTS M̂=i TO M̂
41
PERFORM N-POINT CONVOLUTION
42
MAGNITUDE OF CONVOLUTION RESULT
43
STORE M-TH RESULT
44
ALL SAMPLES DONE?
45
NO
YES
END MLS SPECIFIC REFOCUSING

FIG. 5

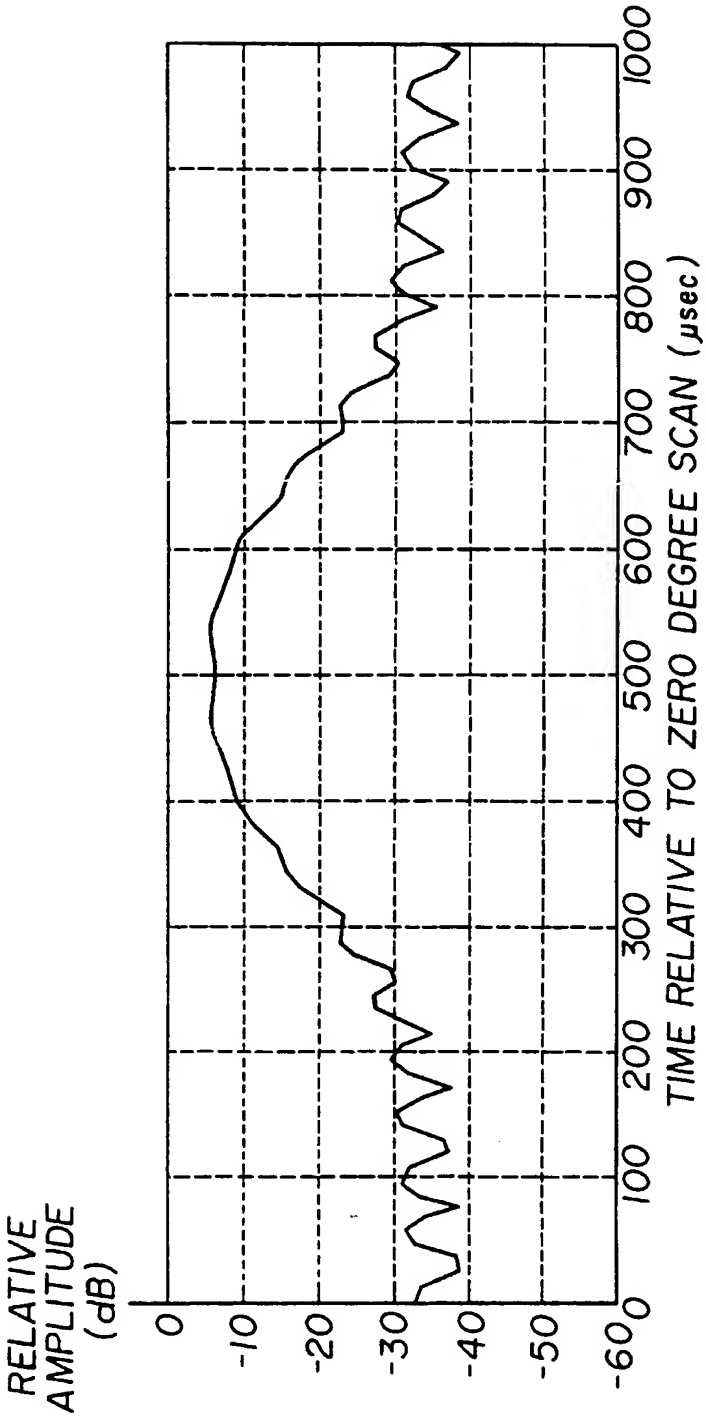
NEAR-FIELD PATTERN
RELATIVE AMPLITUDE (dB)
0
-10
-20
-30
-40
-50
-60
0
100
200
300
400
500
600
700
800
900
1000
TIME RELATIVE TO ZERO DEGREE SCAN (μsec)

FIG. 6

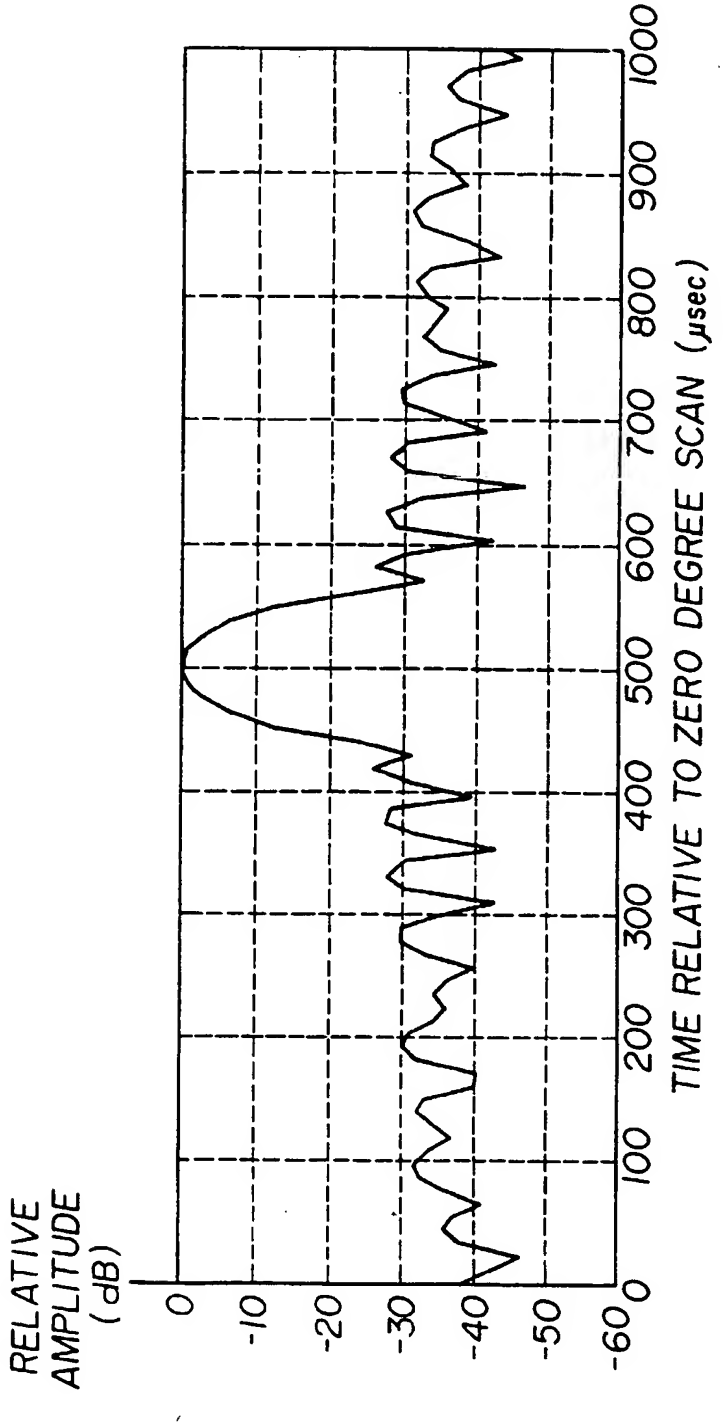
REFOCUSED NEAR-FIELD PATTERN
RELATIVE AMPLITUDE (dB)
0
-10
-20
-30
-40
-50
-60
0
100
200
300
400
500
600
700
800
900
1000
TIME RELATIVE TO ZERO DEGREE SCAN (μsec)

FIG. 7

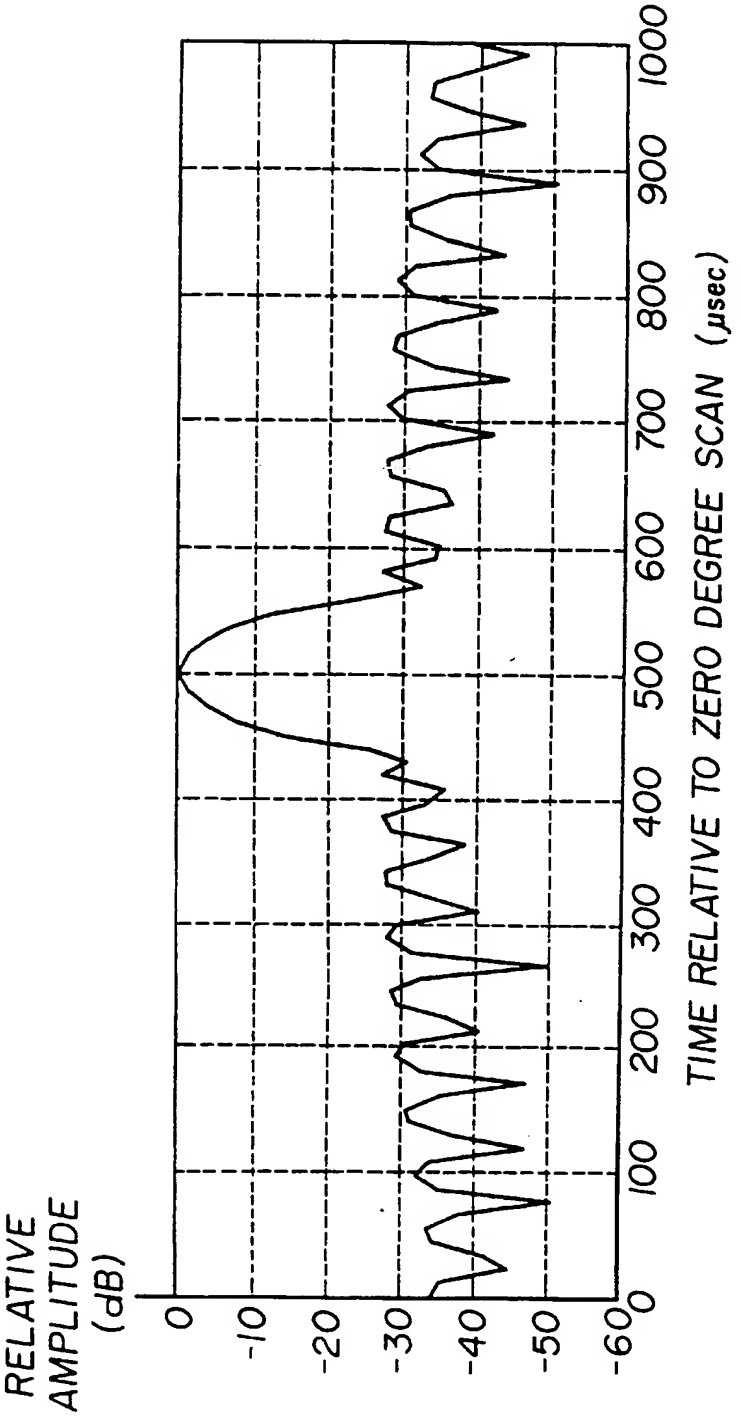
FAR-FIELD PATTERN
RELATIVE AMPLITUDE (dB)
0
-10
-20
-30
-40
-50
-60
0
100
200
300
400
500
600
700
800
900
1000
TIME RELATIVE TO ZERO DEGREE SCAN (μsec)

FIG.8

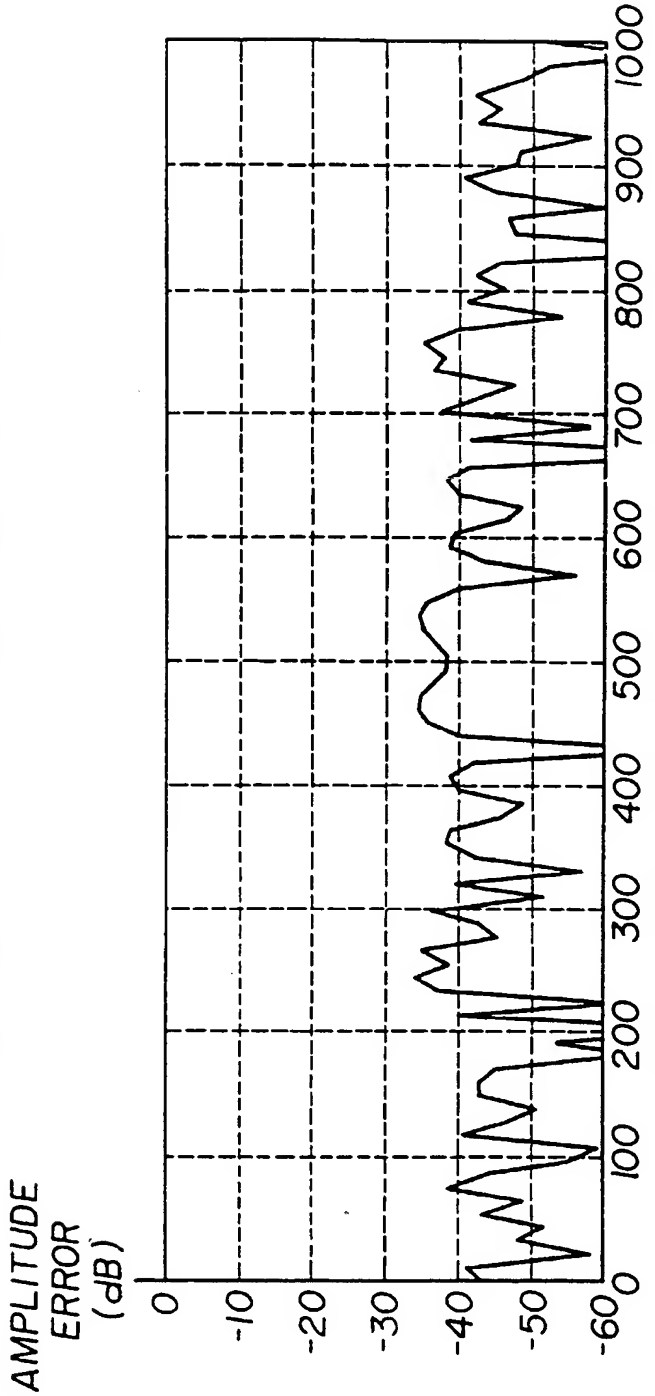
RESULTANT ERROR
(TRUE FAR-FIELD VS. REFOCUSED NEAR-FIELD PATTERN)
AMPLITUDE ERROR (dB)
0
-10
-20
-30
-40
-50
-60
0
100
200
300
400
500
600
700
800
900
1000
TIME RELATIVE TO ZERO DEGREE SCAN (μsec)

FIG. 9